Mechanical Components Diagnostics Research

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Tribology & Mechanical Components Branch

Drive System Team Mission

- **Conduct basic research and technology development on mechanical components and drive systems.**
- **Results lead to first principle understanding of complex phenomena of component or system operation in normal and extreme conditions.**
- **Technology transfer results in improved operation efficiency and safety of Rotary Wing Aircraft.**

Technologies for Propulsion – Drive Systems

- **Advanced Drive System Components and Systems**
  - Multi / variable speed drives
  - Improved gear alloys
  - Enhanced gear operation / control
  - Composite material application to dynamic components
  - Modified geometry gear design, bearings & system arrangements

- **Lubrication Technology**
  - Improved loss-of-lubrication (longer time, lighter weight,…)
  - Reduced power loss – windage drag reduction

- **Condition Based Maintenance (CBM)**
  - Improved detection techniques – i.e. non-metallic sensors
  - Improved data algorithms
  - Validated methods – rotorcraft field verification

What is CBM?

- Condition Based Maintenance:
  - Application and integration of processes, technologies and knowledge via a systems approach to improve aircraft reliability and maintenance effectiveness [1]

- Goals:
  - Reduce maintenance burden
  - Increase aircraft availability
  - Improve flight safety
  - Reduce cost

RW CBM Focus - Propulsion

Propulsion System Health

- Improved detection techniques
- Improved diagnostic algorithms
  - Multi-sensor data fusion
  - Performance metrics
  - Damage magnitude assessment
- Validated methods – rotorcraft field verification
  - Test methods representative of fielded faults
- Future prognostic algorithms
  - Damage life prediction models – predict remaining useful life

Structural Health & Exceedance Monitoring

- Correlate aircraft operational parameters to component life.

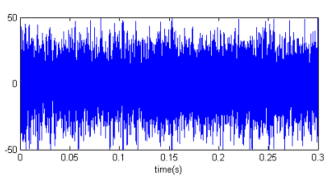
Research enabled through partnerships between NASA, FAA and Army

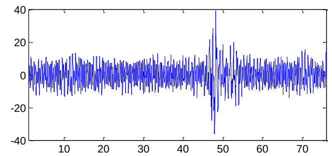
Condition Indicators (CI)

- A measure of detectable phenomena, derived from sensors that show a change in physical properties related to a specific failure mode or fault. [1]

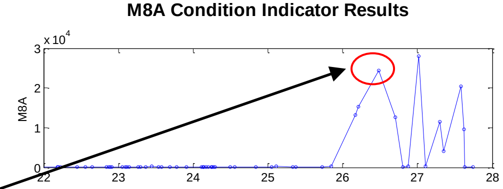
Vibration-based Mechanical Component Diagnostics

Raw Data Snapshot → Algorithm → Condition Indicator (CI)





$$\mathrm{M8A} = \frac{N^4 \sum_{k=1}^{k=N} \left(d_i - \bar{d}\right)^8}{\left(\sum_{k=1}^{k=N} \left(d_i - \bar{d}\right)^2\right)^4}$$



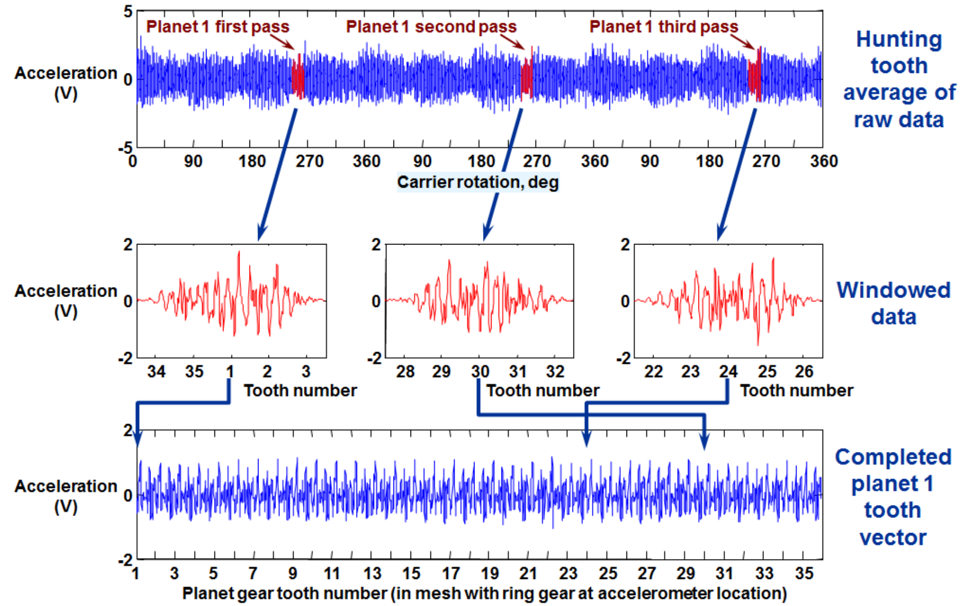
Planetary Fault Detection

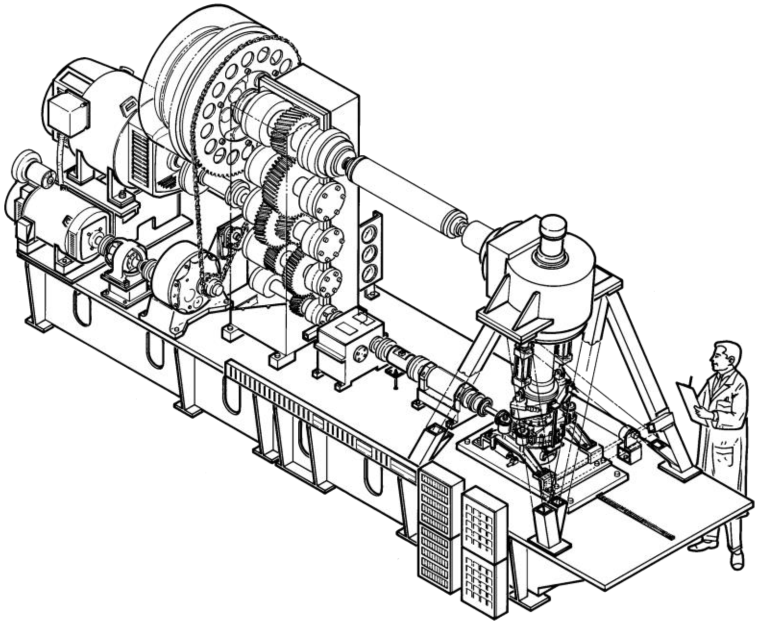
Objective:

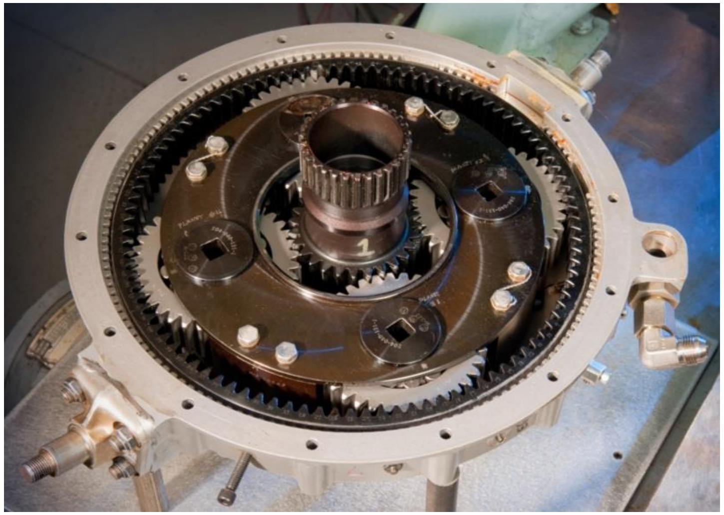
Demonstrate diagnostics to detect gear and bearing planetary system faults in main-rotor gearbox

Approach:

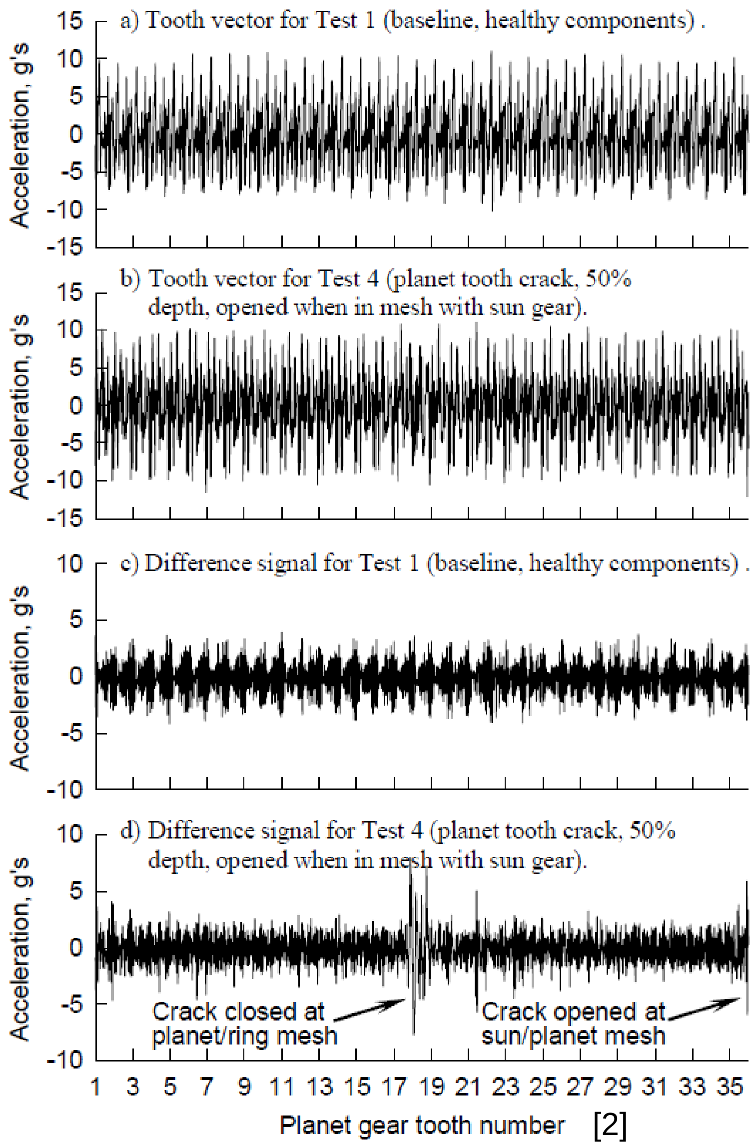
Develop algorithms from seeded fault tests on the OH-58 main-rotor transmission (AATD/Bell OSST)

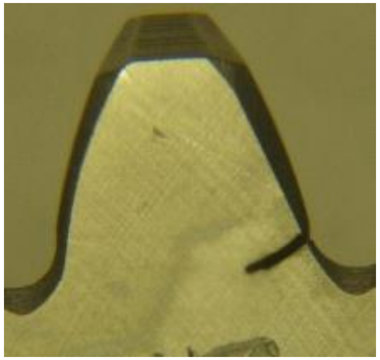


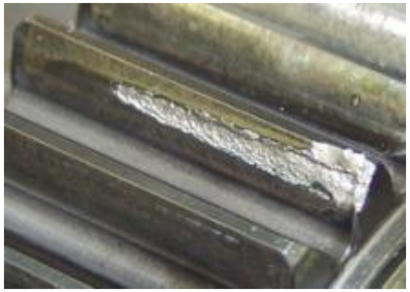




Planetary Fault Detection







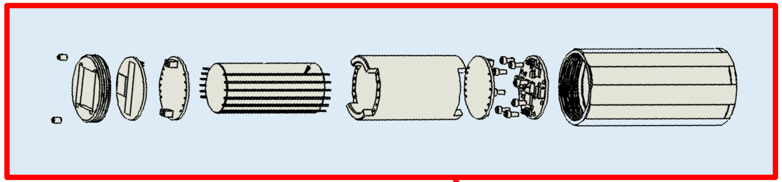
Status:

- Project complete
- Successfully identified the presence and location of a planet tooth crack in a blind test
- Sun tooth cracks were not detected with this method.

SBIR – Embedded Data Acquisition Tools for Rotorcraft HUMS (Ridgetop)

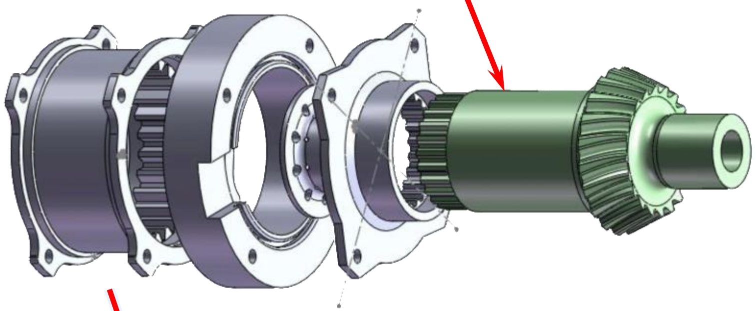
Objective:

Develop MEMS wireless sensor for fault detection in rotorcraft transmission applications



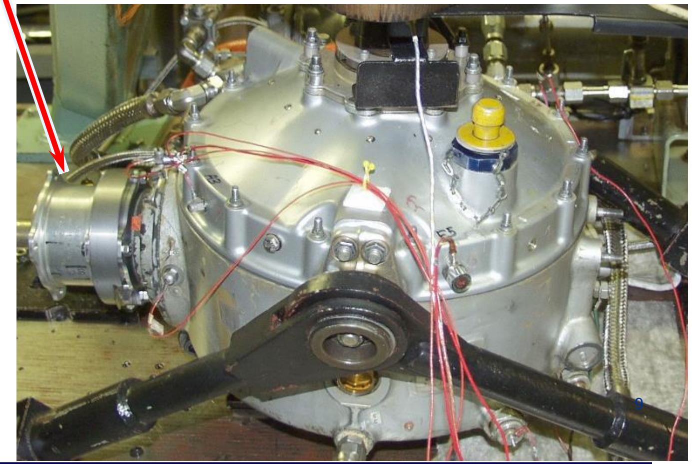
Approach:

- Develop MEMS vibration-monitoring accelerometer, microcontroller conditioner, wireless transmitter, and receiving unit for data collection.
- Mount directly on helicopter transmission component of interest to measure abnormalities and faults.

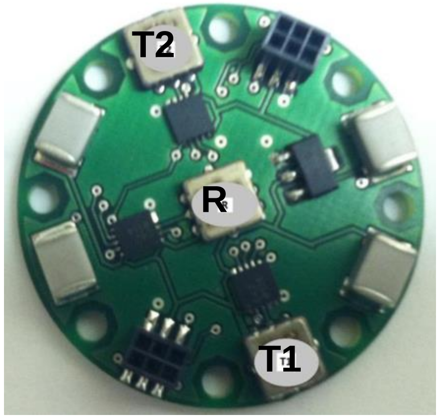


Status:

- OH-58 pinion tooth crack detection test completed after 110 hrs.
- MEMS sensors operating successfully, detected tooth fracture.
- MEMS tests for planetary planned.

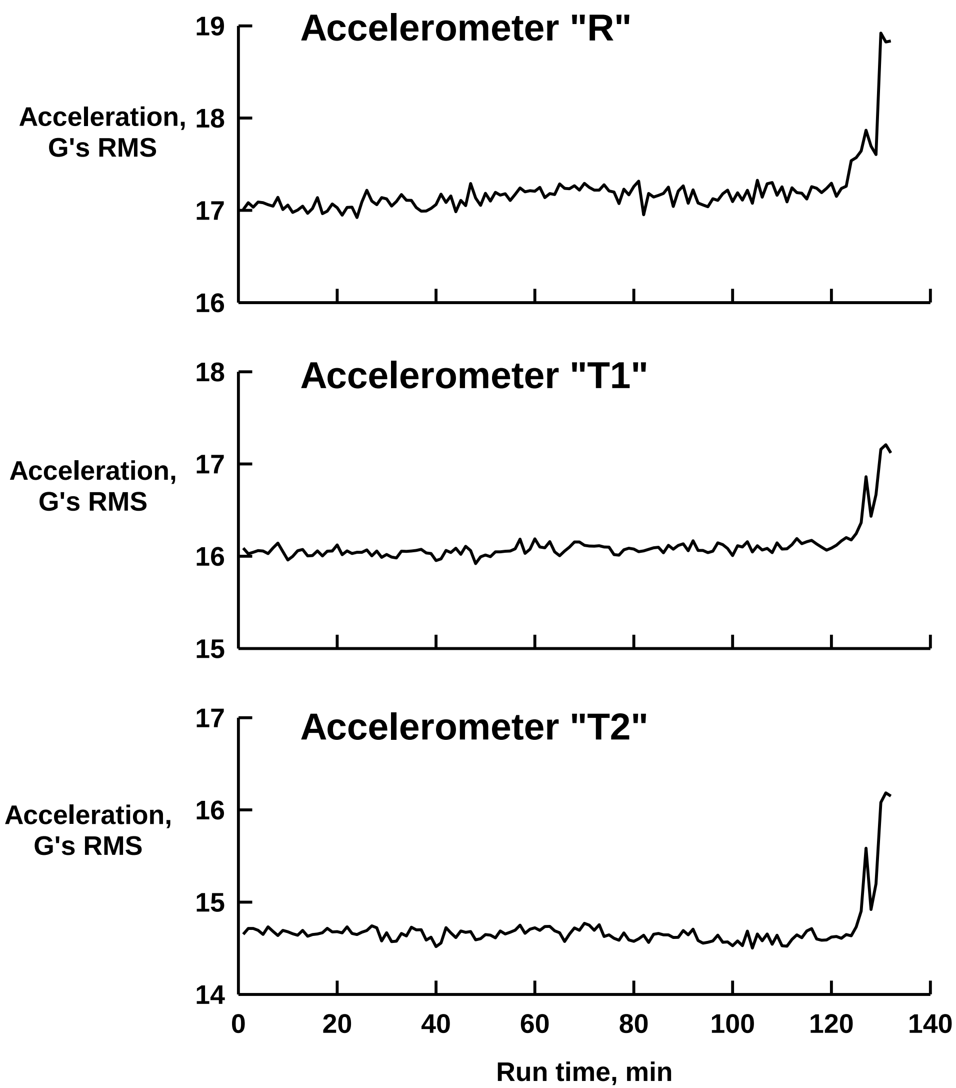


SBIR – Embedded Data Acquisition Tools for Rotorcraft HUMS (Ridgetop)



MEMS Accelerometers

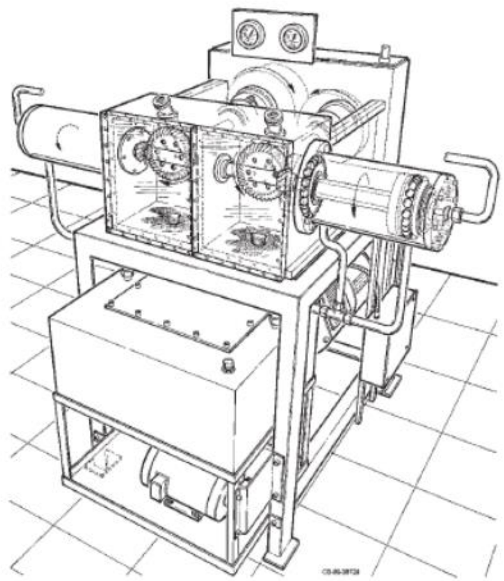
Last Day of Testing



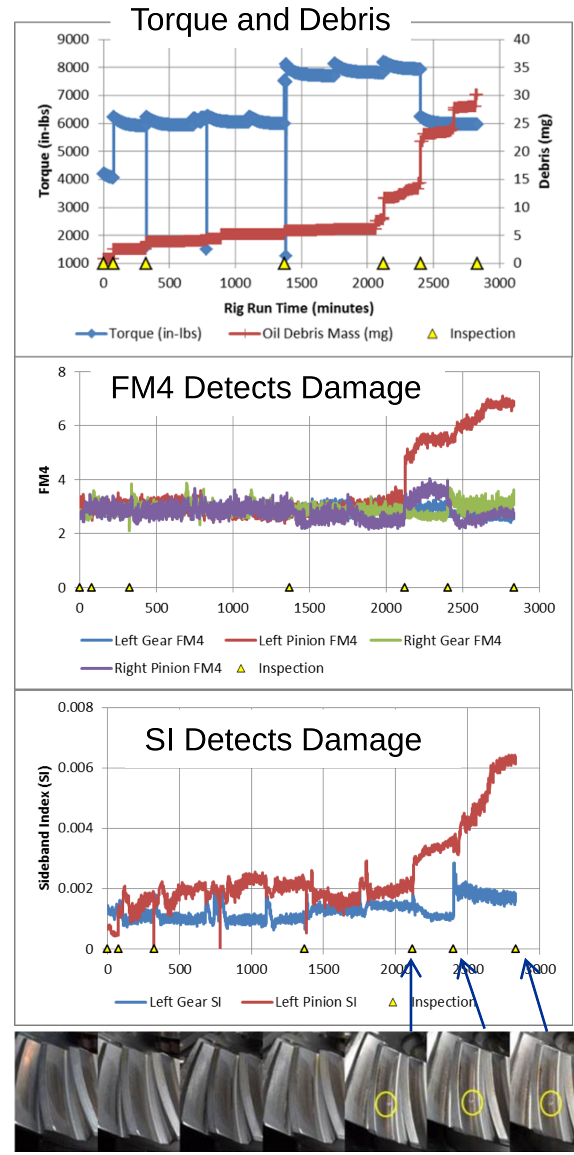
CI Performance in the Lab

Objective:
- Develop CI validation methods in the lab that better represent fielded faults
- Identify limitations using rig tests

Approach:
- Perform tests in GRC Rig
- Evaluate CIs during naturally occurring faults.
- Define Fault: Class, Mode, Degree
- Document fault progression
- Verify (CI) Response
- Correlate faulted helicopter gears

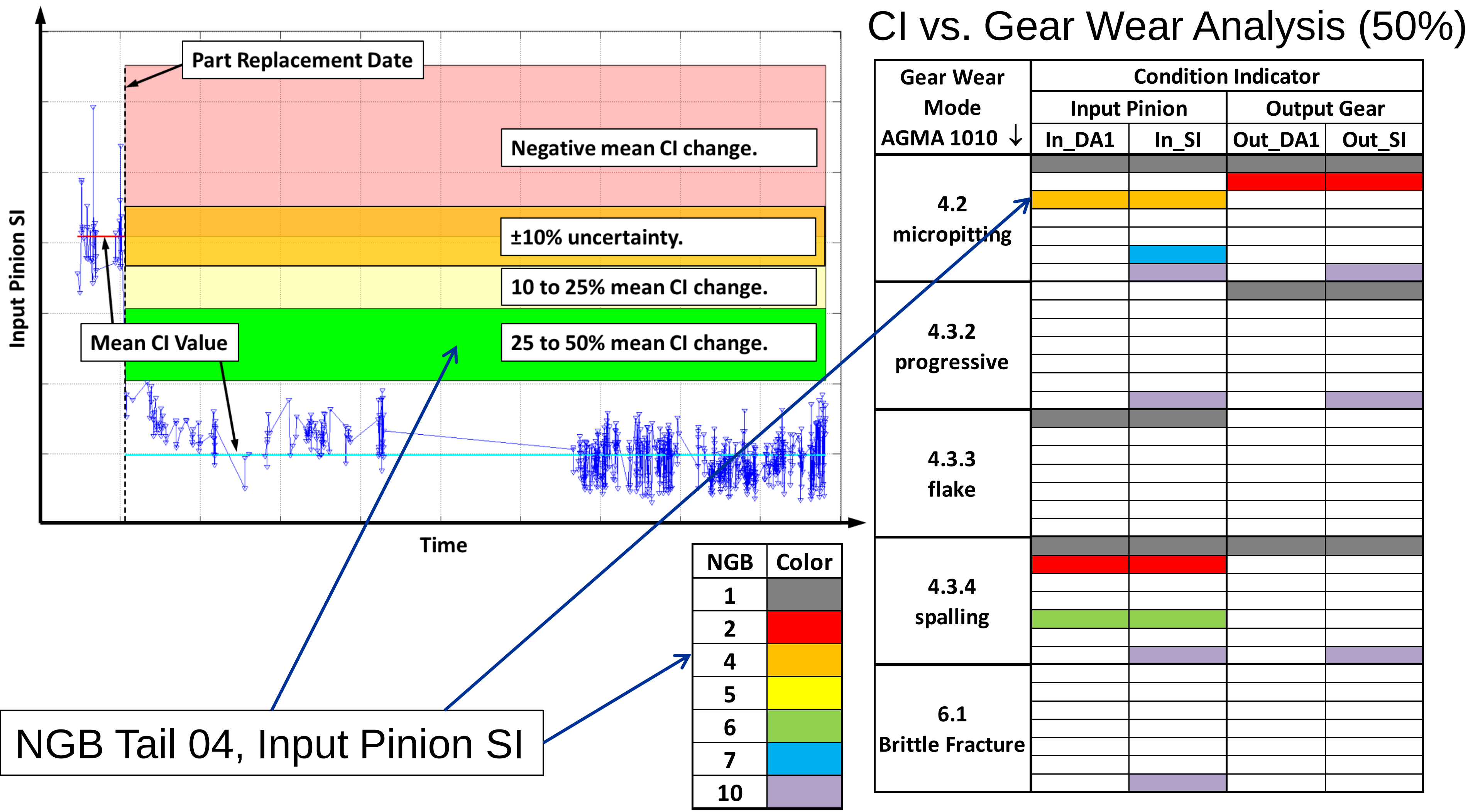


Spiral Bevel Gear Fatigue Test Rig



CI Performance in a Helicopter

CI Performance/Sensitivity to Specific Gear Wear Modes



Hybrid Bearing Fault Detection

Objective:

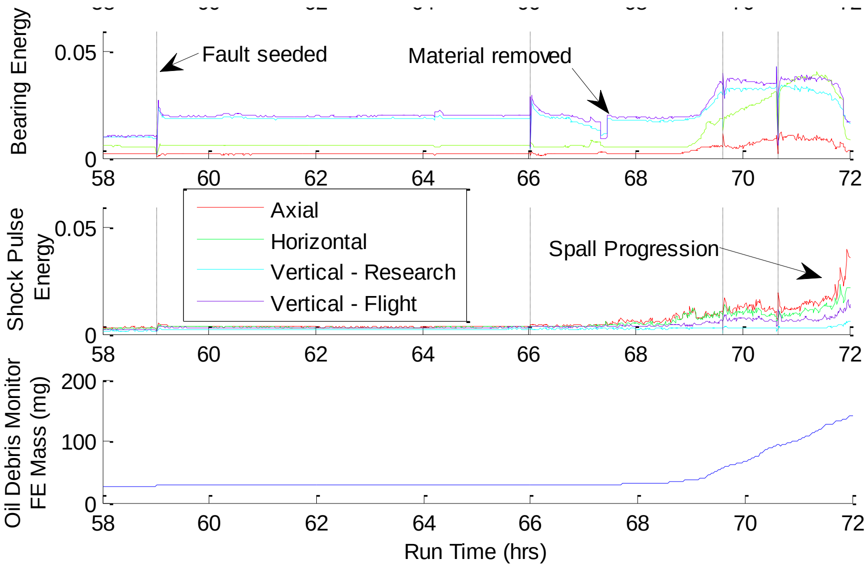
- Conduct seeded fault experiments of both standard (steel rolling element) bearings and hybrid (ceramic rolling element) bearings to examine the difference in damage vibration and propagation
- Determine the effectiveness of currently used flight sensors as compared to higher bandwidth research sensors

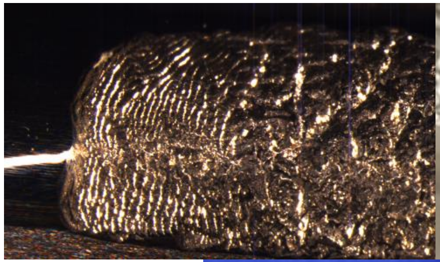
Approach:

- Obtain healthy data under normal loading conditions, seed fault and propagate under normal conditions
- Seed damage using a hardness tester and monitor the vibration change during propagation under normal loading

Status:

- One hybrid and one steel test completed
- Steel bearing ran for 50 hours after material removal
- Test rig load path concerns
- A fixture has been designed to make the process of seeding bearing faults with a hardness tester in angular contact bearings more repeatable





Questions

[1] US Army, “Aeronautical Design Standard Handbook for Condition Based Maintenance Systems for US Army Aircraft,” ADS-79C, January 2012.

[2] D. G. Lewicki, K. E. LaBerge, R. T. Ehinger, and J. Fetty, “Planetary Gearbox Fault Detection Using Vibration Separation Techniques,” presented at the 67th American Helicopter Society Annual Forum, Virginia Beach, VA, 2011.